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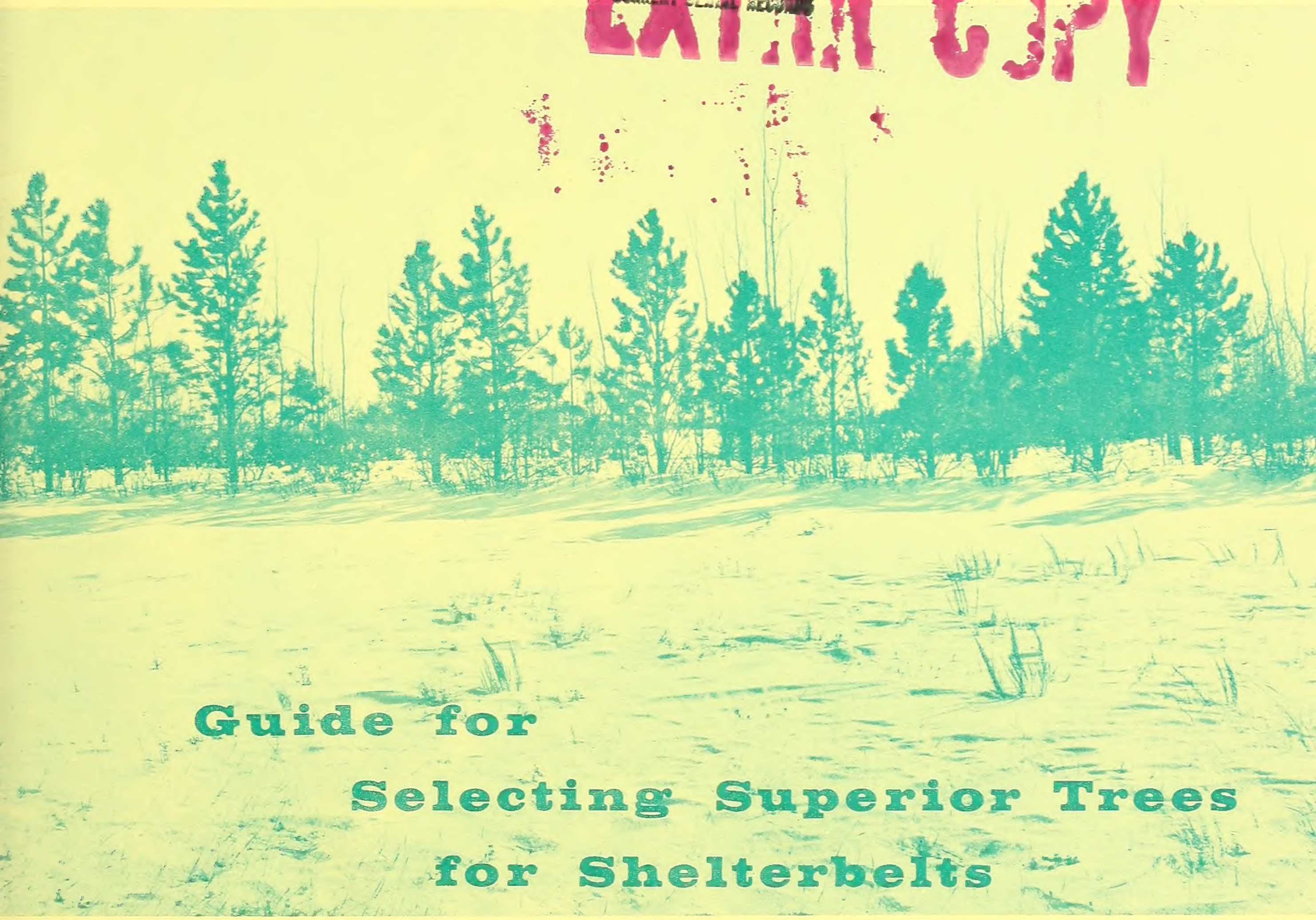

Guide for Selecting Superior Trees for Shelterbelts in the Prairie Plains

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Dawson, David H. and Read, Ralph A.

1964. Guide for selecting superior trees for windbreaks in the Prairie Plains. Lake States Forest Expt. Sta. St. Paul, Minn. 22 pp. illus. (U.S. Forest Serv. Res. Paper LS-13)

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CONTENTS

INTRODUCTION

One of the major needs in Plains forestry, from the aspect of both research and field application of practices, is for genetically improved plant materials for use in wind barrier plantings.

It is commonly recognized that individual trees of the same species differ in observable characteristics. Some of the most obvious traits that seem to vary within a species are growth rate, color of foliage, size and density of foliage, angle of branching, width of crown, time of flushing and defoliation, straightness of stem, and resistance to drought, winter injury, insects, and disease. Some of the differences are due to site condition or to treatment after becoming established on that site, but some of the expressed traits are hereditary and will be passed on to progeny.

We need to seek out trees that manifest desirable traits so that we can bring about genetic improvement of the plant material used in shelterbelt plantings. We realize that some of the desirable traits of the superior phenotypes may not be inherited by their progeny, but others doubtless will.[1]

A program involving the selection of superior phenotypes will provide an immediate source of seed or vegetative material for production of nursery stock in the public and private nurseries. (Usually trees selected for this purpose will exhibit *several* traits which are "superior.") It will also serve to assemble phenotypes of both native and exotic species exhibiting one or more traits distinctly different than those exhibited by the bulk of the population. Such material may be very useful to research organizations for further testing and breeding purposes.

This publication defines some of the important desirable characteristics in shelterbelt species and thus provides a standard to aid in the selection of superior trees by field personnel interested in the tree improvement program. It is also intended to stimulate interest in the need for tree improvement among field technicians and encourage them to participate in locating superior plant materials.

Little research data have been collected concerning the most desirable traits for shelterbelt trees. There is a need for more information on the heritability of many traits as well as for more precise detection of these traits in the field. It may be a long time, however, before more precise criteria on these factors become available. In the meantime, considerable progress can be made by applying the knowledge we have. This interim guide has been prepared to summarize current knowledge and to help steer early efforts in a common direction.

WHAT TO LOOK FOR

The initial selection program for improving shelterbelt trees will involve a search for superior stands and seed sources, superior trees, and unusual trees.

Superior Stands

Within the Prairie-Plains region and in relatively dry areas adjacent to it are scattered stands of native trees. Some of these may consist largely of desirable trees and may be superior to other stands of the same species in the same general area. Despite the possibility that superiority may reflect unusually good growing conditions and thus may be largely an environmental effect, such stands should be selected and their progeny tested. In the meantime, they could well be used to provide seed for planting programs.

[1] *A superior or "plus" tree is one which in outward appearance is superior in one or more characteristics to the average tree of the same species growing on a similar site (Soc. Amer. Foresters 1958). Trees described on the basis of demonstrable characteristics are referred to as "phenotypes." Similar phenotypes do not necessarily breed alike. An individual tree's hereditary constitution, expressed or hidden, and underlying one or more characters is called a "genotype." It reacts with the environment to produce the "phenotype" (Snyder 1959). Names and dates in parentheses refer to Literature Cited at the end of this report.*

Planted stands (shelterbelts) are probably more widely distributed in the Prairie-Plains than are natural stands. Some of these shelterbelts may display uniformly good development of one or more tree species, and trees of such species should be selected and progeny tested. In some instances, the unusually good development or special resistance to some damaging agent may represent a particular race or seed source. Wherever possible, the original seed source of such plantings should be determined so that it can, if feasible, be used to provide seed for additional plantings.

Planting experience in other regions and countries has indicated that use of well-adapted seed sources is second in importance only to proper choice of species. Frequently certain varieties or races of a species are much better adapted physiologically to a given locality than are others. Some may also exhibit morphological differences. Therefore, seed from the sources producing the best adapted plants should be used in the planting program. This is as true for shelterbelts as for any other kind of plantation.

When information is lacking as to what seed source or sources would probably be most desirable, seed should be collected from a region as similar as possible to the proposed planting sites in growing season, frequencies of summer droughts, other environmental conditions, and latitude.

A continuing research program is underway to test the adaptability of different geographic sources of native and exotic tree species for shelterbelt use. Initially, this research must determine the presence of races[2] in these species, means of readily identifying them, and their ranges of distribution.

Superior Trees

Forest stands and plantations frequently contain trees that differ in certain characteristics from the average of the stand. An examination of any stand of trees probably will reveal about as many trees above average as below average in such important traits as angle of branching, height development, straightness of stem, crown density, live branch retention, and resistance to drought, insects, and disease. An early and necessary step in the tree improvement program is to select those trees distinctly above average (superior) in such characteristics as are desirable for shelterbelt trees. Probably most trees selected will be superior in only one or a few of the important traits, but it is important to find and utilize them.

Unusual Trees

Some trees exhibit characteristics very different than the bulk of the species. Such traits can be extremely slow terminal growth (in relation to lateral growth), causing the "mound" type of habit; extremely acute branch angle, causing a fastigiate growth form; bark or foliage characteristics entirely different than is typical for the species; or a demonstrated adaptation to a geographic area outside the usual range of the species. Trees having such traits may be peculiarly adapted races, mutations, or natural hybrids. Although their traits may not be especially desirable in shelterbelt species, such trees may be valuable as possible genotypes to use in a breeding program and should be reported.

HOW TO REPORT SUPERIOR TREES AND SHRUBS

When individual trees or stands of trees are found which would seem to meet the standards of superior or unusual trees discussed in this guide, they should be reported to the Shelterbelt Laboratory, Lake States Forest Experiment Station, Bottineau, N. Dak., or Rocky Mountain Forest and Range Experiment Station, 110 Plant Industry Bldg., Agriculture College, Lincoln, Neb. A card form of the "Superior Tree Report" shown on the next page is available for reporting purposes.

It is unlikely that any one tree will be found that is superior in all traits, but trees that are outstanding in any of the traits listed below should be reported:

A. *Report trees having any one of the next eight items.*

1. Growth rate: Trees notably superior in height or diameter.
2. Crown development: Good foliage reten-

[2] *In some instances variation doubtless will be found to be continuous (clinal) and not subject to delimitation by boundaries. It may still be possible, even in this event, to determine that seed should be collected within a given territory or zone for best results in a given locality.*

Superior Tree Report

Species of Tree (or stand): ______________________ Date __________

Location: "40" __________ Section ______________ T. __________ R. __________

County ______________________ State ______________________

Owned by: ____

____

(Drainage, roads, trails, other landmarks)

____

____

Reason for selecting the superior tree or stand. Check the main outstanding qualities:

Growth rate __________ Health and Vigor __________

Crown Development __________ Branch Development __________

Stem Form __________ Seed Production __________

Resistance to: Weather Injury __________ Insects __________

Diseases __________ Animal Damage __________

Other ____

Size and age of tree or trees: Total height __________ feet;

dbh __________ inches; age __________ years.

Native source of seed (if known) ______________________

Other information and remarks: ______________________

____

____

Reporter: Name ______________________________________

Address ______________________________________

____

tion, uniform density, moderately broad crowns.

3. Branch development: Good live branch retention; uniform, dense branching habit.
4. Weather injury: Resistance to drought, flooding, cold, sleet, heavy snows, strong wind.
5. Insect damage: Resistance to insect pests affecting the species.
6. Diseases: Resistance to diseases affecting the species.

B. *Report any trees showing unusual development such as:*

7. Dwarf form, fastigiate branching, other extraordinary branching habits.

C. *Report exceptionally good stands, plantations, or shelterbelts composed chiefly of:*

8. Trees of good form, size, and quality. (Plantations and belts should be at least 5 years old.)

Cooperation in reporting SUPERIOR TREES or STANDS will be greatly appreciated. The reports will be checked by U.S. Forest Service Experiment Station staff members attached to the Forest Experiment Field Station located nearest the trees reported. Trees that they consider promising will be evaluated by specialists in forest genetics. The trees passing this examination will be used in breeding programs aimed at developing better forest trees for the Plains. Careful reporting of potential superior trees can contribute substantially to this program.

WHERE AND WHEN TO LOOK FOR SUPERIOR TREES

The Prairie Plains offers a large variety of plant material from which to select superior phenotypes for shelterbelts. Although the naturally forested area in the region is small, there is a considerable amount and variety of woody material, some of which probably represents superior genotypes.

Some of the best sites for selection of superior phenotypes are the shelterbelts 20 or more years old. In many of these plantings a selection process took place in the collection of seed, seedlings, or clonal material. A further selection took place in the nursery and in grading before planting. On site, natural selection has been at work since the trees were planted. As these trees grow larger, the differences in growth characteristics between trees of the same species in the same or different shelterbelts become more obvious. It is not surprising that there is considerable genetic variation among the trees due to the many sources of planting stock used in these plantings. Between 1935 and 1942 alone, a total of 200 million trees and shrubs from many different seed sources were planted in the Great Plains (Read 1958). This variety of material, plus that planted in earlier years, provides an excellent source from which to select superior phenotypes.

Plantations of trees of known seed sources — such as those at the Denbigh Experimental Forest at Denbigh, N. Dak., the Nebraska National Forest at Halsey, Nebr., and Agricultural Research Service Field Stations at Woodward, Okla., and Mandan, N. Dak. — can be excellent sources of superior trees. The performance of these trees from known seed sources under the relatively uniform conditions is a good indication of genotypic characteristics.

In some of the plantations and shelterbelts where mortality of some species and selections is very high, the remaining few trees may be highly desirable variants of the population (Nienstaedt 1960). These trees should be tested to determine if the apparent variance is truly adaptive.

In natural stands throughout the Plains are many of the species of trees and shrubs that are being used extensively in shelterbelts. Species in natural stands that have proven of value are eastern cottonwood, American elm, boxelder, green ash, eastern redcedar, and ponderosa pine. Others such as black cherry, bur oak, and hackberry offer possibilities not fully explored.

Most tree species that cover a wide geographic range consist of a varying number of geographic races that have become adjusted through centuries of natural selection to the various environmental regimes occurring within the range of the species (Kramer and Kozlowski 1960). Phenotypically superior individuals — or stands — can be recognized among these woodlands.

In addition to the natural stands within the area itself, there are, near the borders, "outliers" or disjunct stands of species found in abundance east or west of the Plains area. These trees may prove to be races that are peculiarly adaptive to the environment of the Plains. These stands — sometimes considered "relict" (Potter 1952) — offer considerable opportunity for individual tree selection. Seed source studies to determine variation and relative adaptability to plains conditions are recommended.

Selection for certain traits can take place only at specific times or under certain conditions. Periods following heavy insect infestations, disease epidemics, and climatic extremes such as droughts, ice storms, early or late frosts, and extremely high or low temperatures can be particularly rewarding in selection for resistance to normally injurious agents. The readily discernible effects of some of the agents may be delayed for a considerable time after the tree has been exposed to them, so selection usually should be delayed for a month or more after exposure.

All the traits of a tree are determined to some degree by its genetic makeup, although many of these traits are modified by the environment in which the tree is growing: soil, light, climate, other plant and animal life. Although the exact extent to which these traits are influenced by environment is not known, the following characteristics are generally believed to be heritable:

1. Growth rate (diameter and height)
2. Crown formation
   a. Shape
   b. Density
   c. Size of lateral branches
   d. Retention of live branches
   e. Angle of branching
3. Stem form
4. Soil adaptation
5. Phenological characteristics
6. Resistance to drought
7. Resistance to winter injury
8. Resistance to disease and insect attack
9. Resistance to damaging wind and other detrimental climatic factors
10. Seed-producing capabilities

The complete evaluation of these traits requires much research. But an active program on genetic improvement of shelterbelt planting material for the Great Plains should be started without further delay. It is recommended, therefore, that an active program of selection begin now. This guide can serve as a basis for such a program until better, research-tested methods become available.

Growth Rate

The growth rate or vigor of a tree is expressed largely in its height and diameter growth. *Height is the best, most heritable indicator of vigor,* whereas diameter is much more influenced by environment.

Height is especially important because it contributes substantially to a shelterbelt's effectiveness. Both the rate of growth and the maximum attainable height, compared to the majority of the species population, should be considered.

Extremely rapid growth is frequently a factor contributing to weak wood. All rapid-growing trees should be progeny-tested, however, as some may have wood stronger than average. Furthermore, such trees may be useful in a breeding program to combine rapid growth with strength.

Although diameter growth is not strongly inherited, trees outstanding in this trait should be reported.

The growth rate can be reflected in very young trees, and although undesirable traits present in these young selections can show up later, juvenile vigor is important in shelterbelt species and should be recognized. Seedlings in nursery beds sometimes reflect an inherent vigor and can be selected for further testing. Seedlings for the production of planting stock should not be selected, however, exclusively on the basis of performance in the seedling bed.

Crown Formation

The relative height, width, length, shape, and density of the crown are important in the selection of trees for windbreaks, for these traits largely determine the effectiveness of the wind barrier.

However, the progeny of selected trees will be used as components of many different forms of windbreaks. The windbreaks will vary in structure from one to several rows planted at various spacings. They will vary in orientation from north and south to east and west. They will also be designed and planted to serve different primary purposes such as soil erosion control, snow distribution, or livestock and dwelling protection.

Adding to the problems of the various patterns of windbreak structure and orientation and the purposes for which they are used, the optimum density (or porosity) of a shelterbelt for maximum soil erosion protection or for most uniform snow distribution over the cropland has not been scientifically determined (George 1960).

Caborn (1960), in discussing the influence of density as a factor in shelterbelt efficiency, has stated:

> "On the basis of experiments involving artificial windbreaks in the open and model screens in wind tunnels, it is now recommended that the optimum degree of penetrability to the wind or 'porosity' for a shelterbelt is approximately

40%. Clearly this moderate penetrability as applied to living structures in the field can only be found empirically, but shelterbelts of medium density with no large gaps and a uniform structure all the way to the crown level, would appear to fit this category."

He further states, "No evidence has been forthcoming to substantiate the view that a belt should be more permeable in its lower parts than in the crown space."

Therefore, to fulfill the majority of needs for shelterbelts, those trees with a high degree of foliage production, good live branch retention, and a uniform density should be selected.

Variation in the width or broadness of crown should be noted. Generally, trees with moderately broad crowns are most desirable; however, the tendency for apical dominance and strength of branches should not be sacrificed.

Density is determined by component factors of angle of branching, thickness of branches, number of branches, live branch retention, and kind and amount of foliage. The density of the crown may be judged in field observations for reporting purposes with a subjective rating of dense, medium, or sparse. (See later illustrations for individual species.) Because wind protection is essential during the entire year, the density of deciduous trees is best evaluated when the trees are without foliage. Foliage production, however, does contribute to summer density and is also a factor to consider. On deciduous trees, the size of leaves and the degree to which foliage is retained in fall could be significant characteristics in tree selection. In coniferous trees, foliage production, years of needle retention, and relative needle length are extremely influential in establishing a density rating.

Stem Form

Stem form is very important in selecting trees for timber production and less important in selecting trees for windbreaks. A windbreak composed of straight trees would conceivably have more even density than one in which crooked trees were used. Also, in view of the mass of wood being produced by trees in shelterbelts, those specimens that exhibit a desirable stem form for wood production should be preferred, but trees with slightly crooked stems that manifest other *plus* characteristics should also be included in selection. Forked trees are undesirable.

Soil Adaptation

The shelterbelt program in the Plains is in need of trees that are adaptable to alkaline and saline soil conditions. The best evidence of individual trees that can withstand alkalinity or salinity is in shelterbelts and natural stands growing in these soil conditions. Specimens that have survived and remained vigorous probably have a high degree of adaptability to a wide range of soil conditions or are physiologically suited to alkaline or saline soils.

Phenological Characteristics

Although the time of flushing and of maturing current growth is important as a factor in a tree's ability to withstand climatic extremes, the number of months a tree maintains foliage directly affects its ability to act as a wind barrier. Generally, with deciduous trees, the longer the foliage is on the tree, the better the wind protection it can be expected to give. In selecting for this trait, however, consideration should be given to the fact that more severe cold damage may occur to those selections exhibiting this trait.

Late spring frosts often kill back shoots. A sudden drop in temperature may kill back leaves, buds, twigs, and whole branches if tissues are not dormant. Resistance to this damage is generally related to the time of flushing. Those individuals that exhibit a slower rate of bud advancement in the spring or normally break dormancy later than the majority of the species are more apt to be resistant to spring frost damage (Kramer and Kozlowski 1960).

Late spring frost damage can be recognized by dead tips on branches, flower and foliage buds killed, and roots damaged. Conversely, superior phenotypes may be indicated by growth to tips of branches, regular seed production, and maintenance of general vigor.

Frosts in the late summer or early fall, occurring before the tree has entered its dormant period, can also cause severe injury or death. Most temperate zone trees can withstand winter temperatures as low as -50° C. However, the same trees are killed by temperatures slightly below freezing if they are artificially frozen in midsummer (Kramer and Kozlowski 1960). One of the traits related to resistance to early fall frosts is the early maturing of wood (Baxter 1952).

Resistance to Drought

Although precipitation is normally sufficient for the survival and growth of well-chosen and well-managed trees in shelterbelts, certain years of extreme drought have been very detrimental to tree growth and survival (George 1936).

Drought-injured trees die from the top down and from the exposed side inward, but in conifers this symptom may not always be evident because of unequal drying of needles (Baxter 1952). In deciduous species, the leaves turn yellow or reddish, beginning at or near the leaf margins or occasionally midway between the main veins until finally the entire leaf is involved (Boyce 1938).

Trees being judged on their ability to survive drought should be compared with others of their species at the same location, having the same exposure or protection, to eliminate microclimatic and ecological differences. Because trees utilize subsoil moisture, selection should be made not only the year of the drought, but the year after, as drought injury is frequently manifested the second year.

A large number of physiological and morphological characteristics contribute to a tree's ability to withstand periodic droughts. Some of these characteristics are: depth and nature of rooting system, transpiration rate, size of foliage (length of needles on conifers), stomata arrangement and density, and cuticle thickness on foliage. The determination of superiority in these characteristics demands detailed measurements and tests. Progeny tests are necessary to determine the degree of inheritance of these traits.

Resistance to Winter Injury

Injury traceable directly to effects of low temperatures or to desiccation during the cold months of the year may affect tissues above and below ground (Kramer and Kozlowski 1960).

The more widely recognized forms of winter injury include killing back of shoots, frost cracks, "needle burning" of conifers, winter sunscald, cambial injury, and root injury. Individual trees or races vary in their resistance to winter injury.

Winter injury is manifested quite frequently in the Great Plains coniferous species by browning of foliage upon the advent of warm weather in the spring. With severe injury, all the needles and buds are killed and the trees die. More commonly, the older needles are affected the most. Frequently, however, even though all the needles are killed, the buds escape and the trees survive.

The resistance of a particular phenotype to all forms of winter injury is a significant factor in tree improvement work for the Great Plains. Trees should be compared with their immediate neighbors in spring to determine any resistance they might have. Winter injury is usually fairly obvious. Comparisons with other trees of the same species and seed origin should be made on the same sites, as site conditions greatly influence the degree of winter injury a tree may suffer.

Resistance to Disease and Insect Attack

To survive and be effective, windbreak trees must be resistant to diseases and insect attacks. Yet such trees are particularly vulnerable to such injury.

Although the species used in Plains shelterbelts are the ones best adapted to the growing conditions, most of them do not fare as well as in their native habitat. Because of the adverse environmental conditions, such as lack of sufficient rainfall, severe winters, and alkaline soils, tree vigor is frequently reduced (Wilson 1962). Furthermore, many shelterbelts are composed of one or only a few rows of trees, and such a belt can easily lose its effectiveness as a result of a single insect attack (Wilson 1962).

It is possible that individuals of shelterbelt species can be found that are relatively free from an insect or disease that is damaging neighbors of the same species. No one individual or race is likely to be resistant to all diseases and insects which at times attack the species, but it is not unusual to find individuals resistant to a particular disease or insect.

Resistance to Damaging Wind and Other Detrimental Climatic Factors

Local wind, hail, sleet, and heavy snow storms damage trees noticeably. It is likely that certain individuals will exhibit much less storm damage than their neighbors of the same species. These trees may be genetically superior in their ability to withstand such adverse conditions.

Seed Producing Capabilities

Seed production does not contribute directly to the effectiveness of a shelterbelt. However, it should be considered as a desirable trait in a tree that also has other superior characteristics because reproduction of most superior trees will be from seed.

Frequently, decadent or damaged trees produce large quantities of seed. Such trees should not be chosen if they are inferior in other traits.

TRAITS OF IMPORTANCE IN PARTICULAR SPECIES

In addition to the traits described that may be indicative of genetic superiority in all species, there are special traits to look for in individual species. Some of these are listed on the following pages.

Ponderosa Pine

Ponderosa pine (*Pinus ponderosa* Laws) for use in the Plains area should be selected for superior vigor, drought resistance, resistance to winter injury (needle browning), needle retention, broad dense symmetrical crowns, and above-average live branch retention. Trees should be selected for resistance to damage from tip moth (*Rhyacionia* spp.), Black Hills beetle (*Dendroctonus ponderosae*), and sawflies (*Neodiprion* spp.). Trees resistant to root and butt rot (*Fomes annosus*) and blister rust (*Cronartium* spp.) particularly, should be sought (Curtis and Lynch 1957). Because there have been considerable difficulties in establishing field plantings, it would be well to report seed sources (if known) of planting stock that established unusually well (figs. 1-5).

F-506423

FIGURE 1. — A phenotype of ponderosa pine desirable for shelterbelt planting. This tree is growing in a 25-year-old plantation. Note the medium, uniform density, high degree of live branch retention, full, relatively broad crown, good rate of height growth without spindliness, and good seed production.

F-506424

FIGURE 2. — Phenotypes of ponderosa pine in a natural outlier in Nebraska, showing variability of crown forms. The fastigiate form on the left of the group is of particular interest for breeding, but one of the wider crowned forms would be better for shelterbelts. Note the differences in branch retention characteristics.

F-493112
FIGURE 3. — Two ponderosa pine trees with different characteristics growing in a shelterbelt. Although the tree on the left is taller, it has a sparse, narrow crown and exhibits poor branch and needle retention. The tree on the right is better suited for shelterbelt use because it has a medium-broad crown, medium density, and superior live branch retention.

F-486519
FIGURE 4. — Ponderosa pine in a 67-year-old stand in northeastern Nebraska. This stand has proved its ability to survive under severe Plains conditions. The sweep in lower branches may be an inherited characteristic. Crown form of the tree in the foreground is good for shelterbelts.

Eastern Redcedar and Rocky Mountain Redcedar

Eastern redcedar (*Juniperus virginiana* L.) and Rocky Mountain redcedar (*Juniperus scopulorum* Sarg.) have been used with a high degree of success in the Plains States (George 1953, Read 1958). They could be even more valuable trees for shelterbelts if they grew taller.

There is a pronounced racial variation within these species (Williamson 1957).

Phenotypes should be selected for superior height growth in the Northern Great Plains conditions, for variations in the usually very dense crown development, and resistance to winter burn (figs. 6, 7).

F-506425
FIGURE 5. — Ponderosa pine in a 25-year-old shelterbelt. The two trees indicated by arrows have superior characteristics. The tree on the right exhibits superior height growth, a straight stem, uniform medium density, and has a medium-broad crown. A greater crown density and a higher degree of live branch retention would be desirable. The tree on the left shows better-than-average height growth and has a desirable broad, dense crown.

F-502141
FIGURE 6. — The tree indicated on the left in this redcedar windbreak is desirable for shelterbelt planting because it has a broad crown (particularly near the top of the tree) and even density and because it is taller than the other trees in the belt.

White and Blue Spruces

White spruce (*Picea glauca* (Moench) Voss) and blue spruce (*P. pungens* Engelm.) have been used extensively in shelterbelts on all but the most arid sites in the Northern Great Plains. George (1953) reports that these species at Mandan formed effective shelterbelts but that they should be used on only the more favorable moisture situations. Spruces are difficult to establish in dry seasons.

Superior phenotypes of spruce are undoubtedly present, although little is known about the racial variation, particularly in *P. glauca* (Nienstaedt 1957).

Superior spruce trees should be selected for uniform density. Because of their greater density compared with some other shelterbelt species, both phenotypes that are sparse *and* those that are dense should be selected.

Identification and isolation of races resistant to drought and winter injury would enlarge the practical range of spruce species.

Although there have been few insect and disease enemies of spruces reported in the Plains area, *cytospora* canker does affect some blue spruce trees, and phenotypes evidencing resistance should be chosen (figs. 8-10).

F-506426, 27
FIGURE 7. — Two common growth forms of Rocky Mountain juniper. The short, multiple - stemmed type represented by the specimen on the left normally would not attain the height growth of the type represented by the straight, single-stemmed specimen on the right. Unless progeny are to be used for a dense shrub row in a shelterbelt, selections should be made from the single-stemmed type.

Arizona Cypress and Arborvitae

The Arizona cypress (*Cupressus arizonica*) and arborvitae (*Thuja* spp.) hold great promise for use in windbreaks in the southern Plains (Kansas and southward). Both species function well as dense lower and middle-level components with greater drought hardiness and longevity than most broadleaf trees.

E. W. Johnson, at the Agriculture Research Service Field Station at Woodward, Okla., has already done some selection in both species; the results appear much superior to the general run of stock. Further selection is needed for certain types of crown form and adaptive traits for soils in Southern Plains (fig. 11).

Loblolly Pine and Shortleaf Pine

The loblolly (*Pinus taeda* L.) and shortleaf (P. *echinata* Mill.) southern pines have been used in Plains windbreaks in Oklahoma, Kansas, and Texas. Both species offer exceptional promise as the tall, long-lived component of field windbreaks. The average total height of loblolly pine near Vernon, Texas, at 20 years of age was 26 feet.

If improved materials of these species are developed especially for the Plains, their use in windbreaks would doubtless increase. One of the major problems has been in securing adequate initial survival. Stock selected for juvenile vigor and rapid root growth could help solve this problem.

Selection of drought resistant sources should follow the example set by Zobel, Cech, and Goddard in Texas in which Lost Pines loblolly (130

F-506428
FIGURE 8. — A phenotype of spruce more desirable than most of the species for shelterbelt usage. Note the somewhat rounded, full crown, a tendency toward the columnar growth form, and the uniform density.

F-506429
FIGURE 9. — Twenty-five-year-old spruce in a roadside planting. Note the less pyramidal crown form and more uniform density of those trees marked with arrows. These are a more desirable shelterbelt type.

F-506430

FIGURE 10. — An unusual phenotype of blue spruce at Denbigh, N. Dak. This tree is of interest to the tree breeder because of its accelerated lateral growth in comparison to the terminal growth, resulting in a broad rounded form. It is possible these growth characteristics could be transmitted to progeny. This tree is about half the height of its neighbors. The poor height growth would make it undesirable for shelterbelt use.

miles west of the main distribution) was proved to be superior in drought resistance to more eastern sources (Zobel 1955).

Sources of these two pines should be screened not only for drought hardiness but also for resistance to stem rust and needle cast diseases and tip moth damage. Great variation in crown form can be expected, and selection for Plains material might emphasize crowns of greater density than the general run of southern pine phenotypes.

F-486494

FIGURE 11. — A shelterbelt of Arizona cypress showing variation in height growth and crown development. The taller trees that are maintaining good crown density near the top (as shown by arrows) are most desirable.

Green Ash

Because of the extensive natural range of green ash (*Fraxinus pennsylvanica* Marsh) (Meuli and Shirley 1937), there are likely many different races, some of which probably have superior traits for shelterbelts (Wright 1944). It has been found experimentally that progeny from local seed sources, in general, have been more drought resistant and better adapted to Plains conditions than those from moister regions (Meuli and Shirley 1937, U.S. Forest Service 1937).

The very satisfactory performance of green ash in the shelterbelt program (Read 1958) indicates that the selection of superior phenotypes is well justified in this species. Trees should be sought that are above average in growth rate, drought resistance, straightness of stem, and broadness and density of crowns. A high degree of live branch retention is desirable. Resistance to insect attacks, particularly ash borers (*Podosesia fraxini*), is important. Trees that, when compared to the majority of the species, flush early in spring and retain foliage late in fall are desirable (figs. 12-15).

Cottonwoods and Poplars

Several species, varieties, and hybrids of the *Populus* genus are being used extensively in the Prairie Plains shelterbelt program, particularly in those areas in the eastern part of the zone where effective precipitation and depth of water table are more favorable for their growth.

Vast differences in the growth, form, vigor, crown development, and resistance to disease, insects, drought, and winter injury occur among members of the *Populus* genus.

F-506431
FIGURE 12. — A desirable form of young green ash exhibiting greater-than-average crown density, straightness of stem, good branch retention, and superior growth rate.

F-295456
FIGURE 13. — A natural stand of green ash exhibiting poor form. Note the forked trunks, sparse crown density, poor vigor, and poor branch retention. These trees have shown their ability to survive under Plains conditions, but otherwise they are not desirable types for shelterbelt use.

F-500510
FIGURE 14. — Green ash in a 17-year-old shelterbelt exhibiting good crown density, good live branch retention, and good growth rate. The slight sweep in the trunk of the tree in the foreground is not too undesirable, but the forking in trees in the background should eliminate them from selection.

F-295457
FIGURE 15. — A native stand of green ash. Although the tree in the foreground has a slight sweep in the trunk, it is straighter than most other trees in the stand. The growth rate appears superior. Greater crown density and better live branch retention would make it more desirable for shelterbelt purposes.

Superior trees of this genus would manifest such traits as (figs. 16-20):

- Resistance to canker, scab diseases, and leaf rust.
- Tall, straight trunks.
- Dense, relatively fine branching habit with good branch retention.
- Resistance to breakage from ice and wind.
- Adaptability to alkaline soils.
- Above-average adaptability to low water table sites.
- Above-average longevity.
- Superior vigor.

American Elm

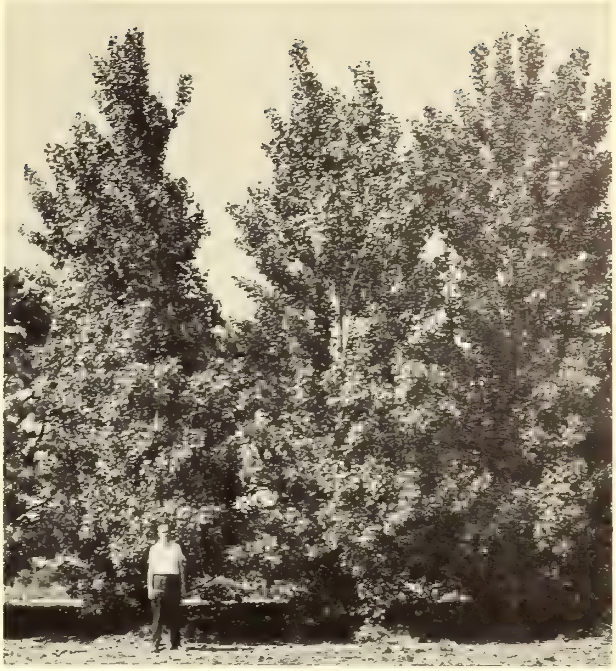
The native American elm (*Ulmus americana* L.) have survived quite well throughout the region in shelterbelt tests (Read 1958). Its weakness seems to be an inability to withstand severe drought during extended dry periods, particularly on shallow upland soils (George 1936, Read 1958).

American elm should be selected for drought resistance, growth rate, a tendency toward a horizontal angle of branching, better-than-average branch retention, and dense crowns.

Wilson (1962) reports heavy woolly elm aphid and elm sawfly infestations in the Northern Plains. In years of heavy infestation, phenotypes appearing to be resistant or recovering vigorously from damage should be selected.

Dutch elm disease is a serious problem in the Southern Plains and may well spread to other sectors eventually. Any individuals showing resistance to the disease should be noted (figs. 21-23).

F-506432
FIGURE 16. — Thirty-year-old cottonwood trees. The tree on the left has a medium-dense crown, straight stem, good height growth, and good live branch retention. The tree on the right has a narrow crown, inferior growth rate, and less dense branch habit. The tree on the left is preferred, but even greater crown density would be desirable.



F-506433
FIGURE 17. — A test planting of Siouxland cottonwood 6 years old. This is a rust-resistant selection made by the South Dakota Agricultural Experiment Station. Note the uniform, narrow crown, the rapid growth rate, and good foliage density.

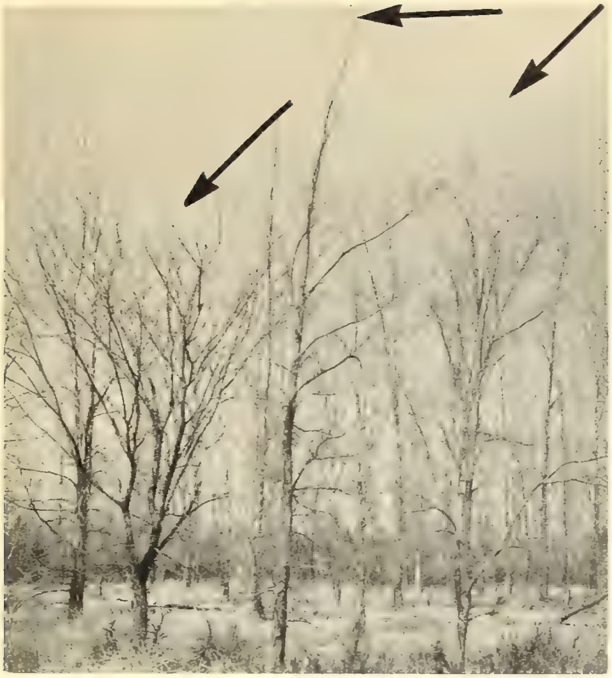
F-506434
FIGURE 18. — A cottonwood exhibiting desirable characteristics. Note the broad crown, excellent density, and good live branch retention.

F-316894

FIGURE 19. — Many of the trees in this 80-foot-tall cottonwood belt in Stutsman County, N. Dak., exhibit superior growth rate, but there is considerable variation in individual trees. Note differences in height, diameter, live branch retention, and straightness of stem. The high percentage of superior trees in the belt should make it a good source of seed for nurseries.

F-506435

FIGURE 20. — Two 30-year-old planted cottonwoods, probably from the same seed source. Both trees are straight, and exhibit good height growth and a high degree of live branch retention. The tree on the right has the ability to retain its foliage longer in the fall than the tree on the left. In this species, this is a desirable characteristic.



F-506436
FIGURE 21. — Three phenotypes of American elm about 25 years old. The tree to the left of center is low crowned, forked at an acute angle, and shorter than others in the same plantation. The center tree is straight, tall, and good in growth rate. Branch retention and density characteristics, however, are not exceptional. The tree at the right has acute branch angles and poor vigor.

F-506437
FIGURE 22. — A desirable form of young American elm. Note the straight central stem, good growth rate, and medium-dense crown. Live branch retention characteristics are fair.

F-500502
FIGURE 23. — American elm in a single-row windbreak exhibiting different crown development. The broad tree to the right of center is probably the most desirable phenotype for shelterbelts. All trees, however, are too young to judge their characteristics accurately. Continued observation of these trees to ascertain whether they maintain these characteristics is desirable.

F-502138
FIGURE 24. — Siberian elm in a shelterbelt in Oklahoma exhibiting a uniform superior growth rate. Trees are 25 years old and average 65 feet tall.

F-431007
FIGURE 25. — Wide variation in frost resistance and winter hardiness is exhibited in *Ulmus pumila* in a 9-year-old shelterbelt in North Dakota. The tree in the center has suffered little or no damage, while the trees to the right and left of it have been frozen back repeatedly.

Siberian Elm

Siberian elm (*Ulmus pumila* L.) is being used rather successfully in shelterbelts where a fast growing, relatively short-lived tree is adequate. Read (1958) showed a 67-percent survival in 567 shelterbelts throughout the Great Plains, and George (1936) reports that losses at Mandan, N. Dak., occurred mostly as a result of freezing temperatures in early fall. He also says, "The late retention of leaves and brittleness of wood make exposed trees subject to wind and sleet breakage." There have been several named selections of Siberian elm, such as "Chinkota," "Harbin," and "Dropmore," placed on the market that appear to be more hardy than the general run of the species (Collins 1955).

It is likely that with the vast amount of this species planted in the Plains in recent years many other better-than-average genotypes may be represented.

F-506438

FIGURE 26. — A good form of native bur oak exhibiting a better-than-average growth rate, straight stem, and relatively dense crown. This tree also flushes earlier than others of the same species on the same site. A more uniform branch habit with live branches retained lower on the trunk would be desirable. The trees in the background exhibit crooked stems and inferior growth rate.

We should seek phenotypes superior in:

Drought resistance.

Resistance to leaf defoliators.

Resistance to slime flux (*Erwinia nimipressuralis*).

Less brittle wood than the species.

Vigorous growth.

Greater longevity.

Good branch retention.

Avoidance of sharp crotches.

Because of the tendency of Siberian elm to be damaged by cold in early fall, comparatively early defoliation is a desirable trait (figs. 24, 25).

Ulmus Hybrids

With the large *Ulmus* population in native stands and shelterbelts in the area, it is quite likely that intraspecific hybrids have been formed. George (1953) reports observations on several *Ulmus* hybrids. One of these has *U. pumila* as one parent and presumably *U. rubra* as the other and is exhibiting good growth form and vigor.

Selectors should be alert to possibilities of natural hybrids within this genus.

Bur Oak

Bur oak (*Quercus macrocarpa* Michx.) is a native drought and cold resistant species that has been used to a limited extent in shelterbelts. It is slow growing and difficult to transplant because of its deep tap root (George 1953). However, the survival at Mandan (George 1953) and in the shelterbelts in Nebraska and Kansas has been very good. The species would seem to merit more extensive trials.

Bur oak has an extensive geographical range and there are recognized differences in races and traits within the species.

Phenotype selections of bur oak should have (figs. 26-28):

Straight trunks, uniform branching habit, and dense crowns.

Ability to establish when transplanted.

Superior seedling vigor.

Rapid growth rate.

Early spring flushing.

Late foliage retention.

F-506439

Figure 27. — Two young bur oaks with desirable characteristics. The tree at the left background has retained some foliage all winter, contributing to greater winter density, but the forked stem is not so desirable. The tree in the right foreground is straight and vigorous and has desirable branching.

F-295443

Figure 28. — Phenotypes of bur oak. The tree on the left has superior growth rate, good branch retention, and a desirable crown density. The forked trunk is somewhat undesirable. The tendency of the tree to maintain foliage later than the majority of the species on the same site is desirable.

Boxelder

Boxelder (*Acer negundo* L.) was used for a long time as a shelterbelt tree. Recently the trend in usage has been downward, presumably because of its tendency to kill back in severely dry years and because of injury from "boxelder blight," induced by 2,4-D damage (Phipps 1963). Boxelder should be selected for resistance to winter injury, longevity, more upright growth forms, and better-than-average branch retention.

Other Tree Species

Although this guide emphasizes only those species of trees that have exhibited a potential as windbreak components, any tree species growing under Plains conditions and exhibiting superior or unique characteristics should be considered for selection. Of particular importance are phenotypes growing vigorously in unusual sites for the species, showing obvious resistance to drought, cold, insects, or disease, or growing well out of their usual range.

Shrubs

The development of a guide for the selection of superior shrubs is intended for a later date. However, outstanding shrubs exhibiting any characteristics that enable them to be more adaptable to Northern Great Plains shelterbelts should be selected. Species of special interest are Siberian peashrub, honeysuckles, lilacs, Russianolive, Amur maple, buffalo berry, and species of the *Prunus* genus.

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